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Procedia - Social and Behavioral Sciences 223 (2016) 509 – 514
Procedia Social and Behavioral Sciences

2nd International Symposium "NEW METROPOLITAN PERSPECTIVES" - Strategic planning, spatial planning, economic programs and decision support tools, through the implementation of Horizon/Europe2020. ISTH2020, Reggio Calabria (Italy), 18-20 May 2016

Interpreting and Predicting Pedestrian Movement in Public Space through Space Syntax Analysis

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Abstract

Creating quality and sustainable urban environments has always been a challenge for urban planners and designers. The modern perception of urban planning is directed towards promoting pedestrian movement and, at the same time, limiting the excessive use of automobiles. For understanding how pedestrian movement is generated in relation to the urban layouts and for predicting this movement in public spaces, GIS database, statistical methods as well as space syntax approaches are used and tested in the case of the Municipality of Athens. In particular, this paper attempts to: (a) interpret and predict densities of pedestrian movement though the effective study of configuration characteristics and syntactic properties of urban space; (b) identify inconsistencies and limitation in the prediction of pedestrian movement; (c) propose a methodological framework to overcome these limitations. Correlation analysis is also performed between the results of axial and segment analysis to establish the syntactic analysis that better simulates the pedestrian movement. This paper is part of a wider research that intents to interpret the characteristics of the public space in order to create, through more holistic approaches, a methodological framework for decision-making analysis towards sustainable urban planning.

Peer-review under responsibility of the organizing committee of ISTH2020

Keywords: Syntactic analysis; Pedestrian movement; Space syntax limitations; Sustainable urban planning.

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Peer-review under responsibility of the organizing committee of ISTH2020
doi:10.1016/j.sbspro.2016.05.312

1. Introduction and concepts

Public spaces play a vital role in the environmental, economic and social development of the city and constitute sources or providers of life quality and sustainability (Chiesura, 2004). In the modern perception of urban planning, when referring to public spaces an integrated and continuous spatial system is considered, where each element (city centre, park, playground, neighbourhood open space in residential areas etc.) is connected in a certain way with the other components, so as to affect the social and economic characteristics of the entire network. In this sense, streets as connectors among public spaces should be considered, analyzed, treated and designed as public spaces themselves. In this particular system, the structure of the urban tissue affects human behavior, i.e. the way in which people are moving and working in the urban space. On one side, the syntactic properties of the urban network determine the accessibility to specific locations and at the same time influences the siting of specific land uses and activities; on the other, the pedestrian movement patterns affect directly the location of specific land uses.

The configuration characteristics of the urban space as well as their impact on pedestrian activity, movement and behavior can be effectively studied through the space syntax approach. According to several studies on a large sample of cities different in form, structure, size and culture, the space syntax theory can efficiently interpret and predict densities of pedestrian movement as spatial configuration correlates powerfully with observed movement by pedestrians. In most cases, a proportional relationship is established between the most important space syntax parameter, i.e. integration and pedestrian density (Talav Era R., 2012; Law et al, 2012; Topçu, M., 2007; Read, 2005; Hillier et al 1993; Peponis et al, 1989; Hillier et al, 1987). Other studies show that also other factors influence the choices of pedestrian movement e.g. land uses, diversity of land uses, connectivity, population densities, average building height (Choi & Koch, 2015; Choi & Sardari Sayyar, 2012;Fatah Gen Schieck et al, 2008; Özbil et al, 2007).

This paper attempted to perform syntactic analysis to investigate this correlation in the Municipality of Athens, in Greece, as this area is a very dense system in terms of population and quite complex in terms of land use mix. The overall purpose is to interpret the densities of pedestrian movement as well as to identify inconsistencies and limitation in the prediction of pedestrian movement and propose ways to overcome them so as to develop a methodological decision-making approach for sustainable urban planning.

2. Performing syntactic analysis for Athens Municipality

2.1. The case of study: Athens Municipality

The Municipality of Athens, which is part of the capital of Greece, is the largest municipality of the country. The area of study has a population of about 665 thousand inhabitants, an area of about 39 square kilometres and a population density of 17,000 inhabitants per square kilometer, which makes is by far one of the densest urban areas in the developed world.

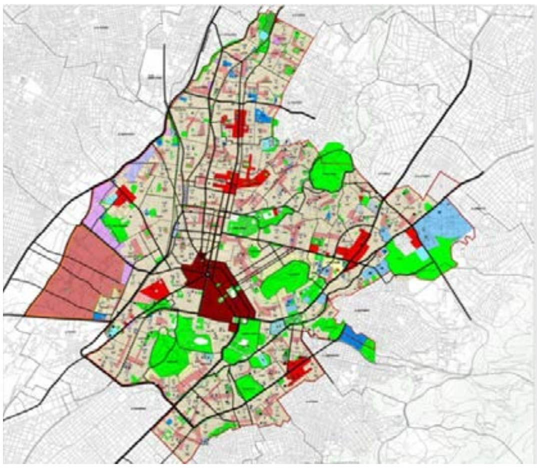

Fig. 1. Master Plan for Athens, Attica, (proposal) ORSA 2011

The municipality of Athens has been formulated over hundreds and hundreds of years and owes its current complexity exactly to this long time route of development and transformations. The postwar urban, socio-economic and population development of Athens led to the current unbalanced over accumulation of population, thus activities, services and job opportunities. As a result, in the greater metropolitan area of Athens almost half of the population of Greece has been accumulated resulting in a significant spatial change on the city's landscape.

The explosive residential development along with the over exploitation of public space resulted to a morphology of very tight urban tissue around the various city centers and the city's several hills (see Fig 1). This expansion of the urban tissue led to an increased use of automobiles.

The main street network that has been developed over the years includes both an irregular configuration of streets in parts of the city center and an axial formulation of major roads beyond the center and towards the periphery. This formation has further led to a linear expansion of commercial, administration and other activities.

This model resulted in investing on the construction of additional roads and further parking spaces instead of improving the public transportation services, and along with the lack of fixed track transport, the use of private cars was encouraged even more, leading to an excessive increase of traffic volume. The current Athens Master Plan aspires to change these trends and strengthen the role of public transport and pedestrian movement.

2.2. Methodology

To interpret and predict the densities of pedestrian movement, syntactic analysis is performed as a first approach in the study area. The initial step of the analysis includes data collection, which is a very important section of this study. Based on the urban street network, open street data were obtained by Open Street Map (OSM) (www.openstreetmap.org), and the axial map is automatically generated, using an open source extension of ArcGIS 10.2, the Axwoman 6.3. In this section, the axial map was shaped and every street was represented by an axis in the maps. Subsequently, the axis lines are imported to an open-source software platform - DEPTHMAP - in order to perform a complete analysis of the different space syntax parameters.

The different variables estimated through the DEPTHMAP software include the connectivity measure, which is the number of elements that are connected to a certain element; the integration measure, which is the distance of an element to all other elements in relation to the number of elements in the complete system; and the choice measure, which indicates how often an element is passed, when calculating the shortest paths between elements (Hillier and Iida, 2005).

For the syntactic analysis, first an axial analysis is performed through DEPTHMAP and the connectivity, integration and choice measures are calculated and illustrated in graphs. Then, a segment analysis is conducted in DEPTHMAP, in which for calculating the graph measures, not the steps from one to another element are counted, but the angles between the intersecting points of the elements. The advantages of segment analysis are the fact that it is more detailed than the axial analysis and that there is better correlation with pedestrian movement observations (Hillier & Iida, 2005).

For the segment analysis, there are three kinds of analysis: metric analysis, topological analysis and angular analysis. The basic difference among the methods is the distance type when calculating the shortest path between two arbitrary segments. For metric and topological analysis the variable of mean depth is calculated instead of integration. After the analysis, the integration measure is also calculated automatically through a formula that divides the total nodes by the mean depth measure for each axial line. As a final step, statistical calculations are performed in order to estimate correlations between axial analysis results and segment analysis results, in order to establish the type of analysis better suited for predicting densities of pedestrian movement.

2.3. Results

First the axial map is automatically generated and presented in fig.2a. Then, the axial analysis includes the production of the global integration map of the municipality and is presented in fig.3a. The red lines show the streets with the highest integration values, while the blue ones show the most segregated ones.

a b

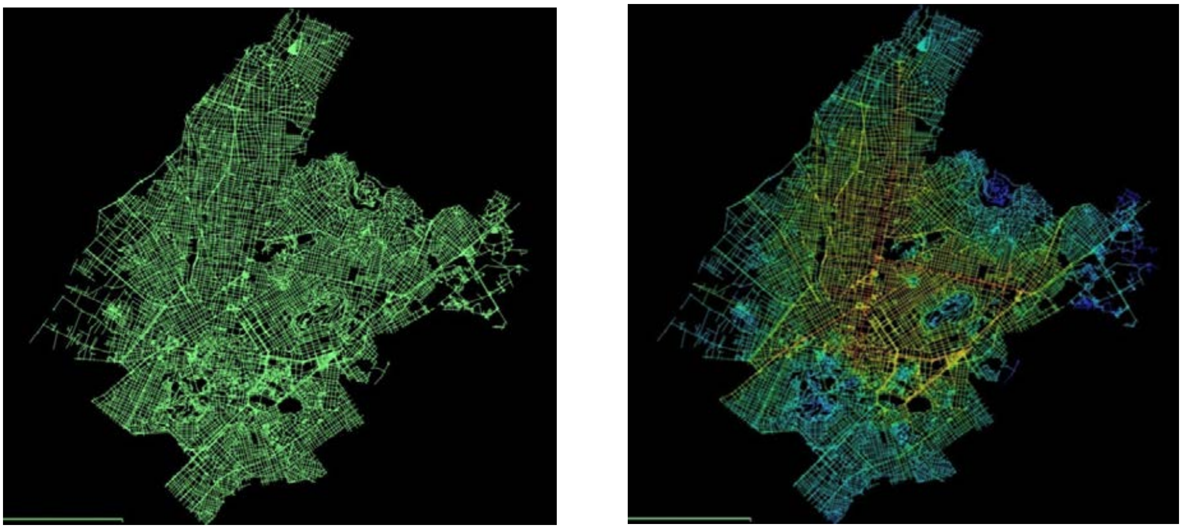

Fig. 2. (a) Axial Map of Athens Municipality; (b) Global Integration Map of Athens Municipality.

The integration core, shown in red, orange and yellow lines, exhibits an axial development penetrating most parts of the municipality while it takes the form of a dense grid over the historical and the central business district (CBD). Segregated spaces, shown in green, light blue and dark blue lines, tend to cluster in the periphery, mostly covering the out of the center area. The choice map of the municipality is presented in Fig.3a, with the highest choice values being red and the lowest being blue.

a b

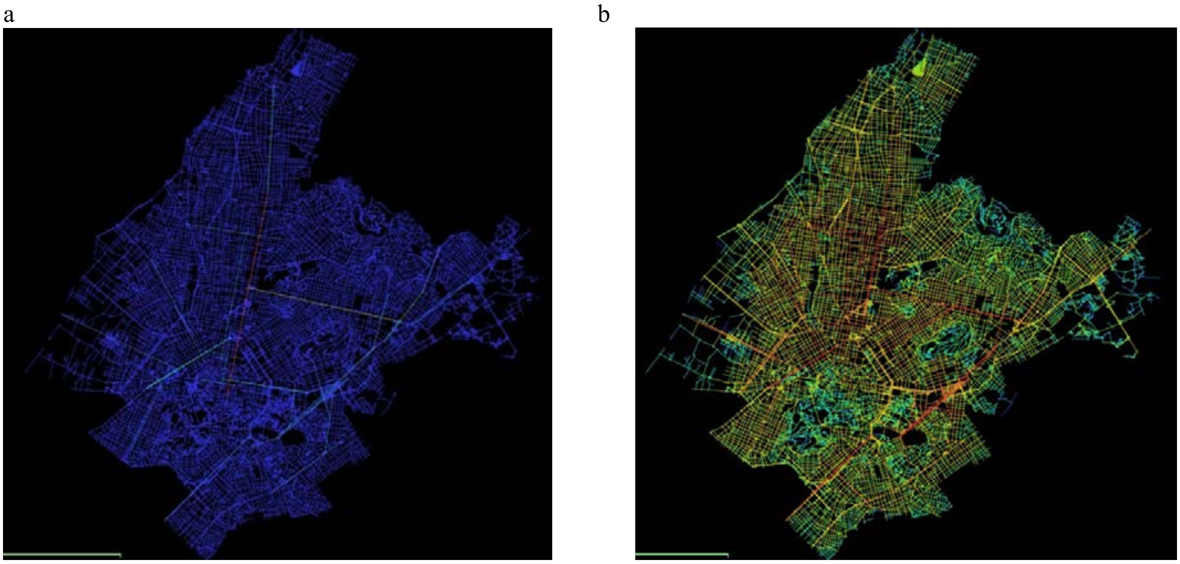

Fig. 3. (a) Choice Map of Athens Municipality; (b) Local Integration Map (radius=3) of Athens Municipality.

According to Hillier (1996), pedestrian densities on lines in local areas can usually be best predicted by calculating integration for the system of up to three lines away from each line, the local scale of integration map (radius=3) is created and illustrated in Fig 3b.

In the analysis it is illustrated that the measures of integration and choice have their higher values in about the same avenues or streets, according to the syntactic properties of the urban space.

The results of the segment analysis are in some cases similar but in other quite different. In particular, the topological analysis results of the segment analysis appear in close relation to the axial analysis, while the results of the metric analysis differ significantly. This is more apparent when looking at the correlation between axial analysis and segment analysis. In table 1, the correlation coefficients (R^2) are calculated for all pairs of measures e.g. choice of the axial analysis with choice of the metric segment analysis.

Table 1. Correlation coefficients (R^2 values) of Choice and Integration to study the correlation between segment analysis and axial analysis.

	Choice (betweenness)		Integration (closeness)	
Analysis	Sum	Average	Sum	Average
Metric	0.44	0.12	0.21	0.37
Topological	0.74	0.92	0.23	0.99
Angular	0.59	0.50	0.20	0.80

From the table it is illustrated that, for the measure of choice, both sum and average summarizations of the topological analysis show a strong correlation between the axial analysis and the segment analysis, R^2=0,74 and R^2=0,92 respectively. The same applies to a larger extend for the average summarization of the measure of integration (R^2=0,99). On the contrary, the correlation in the metric analysis is low for both measures, choice and integration, in both sum (R^2=0,44 and R^2=0,21) and average summarizations (R^2=0,12 and R^2=0,37). Regarding the correlation in the angular analysis, the R^2 values show weak correlation both in sum (R^2=0,59) and in average summarizations (R^2=0,50). As for the measure of integration in the angular analysis, the summarizations of the sums show weak correlation (R^2=0,20), whereas the respective average value show strong correlation (R^2=0,80). Thus, in the specific case study, the segment topological analysis appears to simulate better the syntactic analysis of the urban space and thus predict the densities of pedestrian movement.

3. Limitations on predicting the densities of pedestrian movement

The geographical coincidence of the city's historical centre with the city business centre, and in particular the former being part of the later, implies the creation of a very lively urban environment in the heart of the city. With regards to the city center, the high densities of pedestrian movement charactering the streets can quite sufficiently be interpreted in syntactic terms by the very form of integration core, which strongly covers the whole central area.

However, the correlation between integration values and pedestrian movement densities that have been and empirically observed is not strong for particular spaces of the study area e.g. Hermou Street which is a significant commercial pedestrian street of Athens or Adrianou Street, which is an important street in terms of tourism attraction. Additional inconsistencies have been observed in the area's periphery where the integration values are low (see Fig. 2b), although certain streets exhibiting very high densities of pedestrian movement. These streets host specific land uses and activities that attract pedestrians, e.g. commercial activities, administration services, etc.

The major inconsistences of the integration measure and pedestrian densities from empirical observation appear in: (a) major commercial streets (e.g. Hermou, Athinas, Ifestou street) (b) streets and squares hosting popular cafes, bars and restaurants (e.g. Skoufa street in Kolonaki, Agion Anargyron in Psyri, Heraclidon street in Thissio), (c) streets of historical and touristic interest (Apostolou Pavlou, Adrianou street, etc.) and (d) streets that host popular land uses that attract pedestrians e.g. courts, museums, universities, central bus stations, etc. These inconsistences can partially be interpreted by the irregular urban tissue, especially in the traditional part of the city.

In any case, in these spaces, the particularly high densities of pedestrian movement cannot be fully interpreted by integration or other space syntax variables, as also other factors influence the choices of pedestrian movement. A significant factor is the existence of land uses and activities that work as attractors of pedestrian movement. In other words, it is not only the syntax of these spaces that determine the pedestrian movement but also other factors. Similar conclusions were made in other studies, like for example in the paper of Özbil et al (2007), where observation data in Atlanta yields less strong correlations than those previously obtained by similar studies in London (Hillier et al 1993) or in Greek cities (Peponis et al 1989).

4. Discussion and further research

This paper explores the syntactic properties of an urban tissue in order to interpret and accurately predict the densities of pedestrian movement so as to create a methodological decision making tool for sustainable urban planning. The inefficiency of space syntax to interpret densities of pedestrian movement in particular streets and areas is due to the fact that pedestrian movement is studied exclusively within the context of syntactic properties and structure of the urban system, without taking into account other spatial factors influencing the choices of pedestrians. However, empirical research shows that particular land uses and activities tend to attract pedestrians in the very local area beyond what their syntactic location and properties within the spatial system of the larger area or the city may suggest. Under this perception, the study area can be simulated as a system of "attractors" i.e. land uses that attract pedestrian movement.

A further challenge is to quantify the measure of attraction through particular "weight" values according to the significance of each attractor; an explicit way to implement this is to obtain data of average visitors per week or per month and create an indicator of proximity of the specific land use. A more generic approach is to develop a formula that calculates, within a specific range, the indicator of proximity to a specific land use category. Through this method, a map of the proximity dimension can be produced and incorporated to the integration map of space syntax in order to efficiently predict pedestrian movement and eliminate inconsistencies.

Further research includes field work in terms of observation of pedestrian movement in a targeted sample of streets though strategic "gates" of the study area in order to verify the simulation results. Finally, of course, testing the simulations in other areas of study is important to establish the validity of the methodological tool.

Acknowledgements

Acknowledgement is made to the State Scholarship Foundation – IKY that support financially the PhD thesis through the 'IKY Fellowships of Excellence for Postgraduate Studies in Greece – SIEMENS PROGRAM'.

References

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning*, 129-38.

Choi, E., Koch, D. (2015). Movement and the connectivity of streets: A closer look at route distribution and pedestrian density, Proceedings of the 10th International Space Syntax Symposium, 1-11

Choi, E. Sardari Sayyar, S. (2012). Urban diversity and pedestrian behavior – Refining the concept of land-use mix for walkability. *Proceedings of the 8th International Space Syntax Symposium*, Paper ref no. 8073, p. 1-15.

Fatah Gen Schieck, A., Briones, C., Mottram C. (2008). Exploring the Role of Place within the Urban Space: The Urban Screen as a socialising platform. *Mediacity: Situations, Practices and Encounters*, by Frank Eckardt et al. ISBN 978-86596-182-2. p. 285 – 294.

Hillier B., Burdett R., Peponis J., Penn, A. (1987). Creating Life: or does architecture determine anything? *Architecture and Behaviour, special issue on the work of the Unit for Architectural Studies, Bartlett School of Architecture and Planning*, University College London, p. 233-250.

Hillier, B. (1996). Cities as movement economies. In: Hillier, B. Space is the machine. *Cambridge: Cambridge University Press*, p. 111-137.

Hillier, B., Iida, S. (2005). Network effects and psychological effects: a theory of urban movement. *Proceedings: 5th International Space Syntax symposium*. p. 553 – 564.

Hillier, B., Penn, A., Hanson, J., Grajewski, T., Xu, J. (1993). Natural movement or configuration and attraction in urban space use, *Environment and Planning B: Planning and Design*, Pion, Brondesbury, Vol. 20, p. 29- 66.

Law, S., Chiaradia A., Schwander, C. (2012). Towards a multi-modal Space Syntax analysis, *Proceedings: 8th International Space Syntax Symposium Santiago*, PUC, Paper ref no 8021. p. 1-20.

Organization for the Master Plan and Environmental Protection of Athens (ORSA), Strategic Plan for Athens - Attica 2021, 2011

Özbil, A., Peponis, J. (2007). Modeling Street Connectivity and Pedestrian Movement According to Standard GIS Street Network Representations. *Proceedings of the 6th International Space Syntax Symposium*, İstanbul. p. 1-10.

Peponis, J., Hadjinikolaou, E., Livieratos C., Fatouros D.A. (1989). The Spatial core of urban culture. *Ekistics*, n. 334-335, p. 43-55.

Read S. (2005). Flat City: space syntax derived urban movement network model, *5th Space Syntax Symposium*, Delft

Talav Era, R. (2012). Improving pedestrian accessibility to public space through Space Syntax Analysis, *Proceedings: 8th International Space Syntax Symposium Santiago*, PUC, Paper ref no 8223. p. 1-16.

Topçu, M., Topçu, K. D., Kubat, A. S. (2007), Movement Economy Dependent of Urban Design, Proceedings: *6th International Space Syntax Symposium*, İstanbul. p. 1-6